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CANOTIA

Volume 4, issue 1

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Canotia publishes botanical and mycological papers related to Arizona. These may include contributions to the Vascular Plants of Arizona project, checklists, local floras, new records for Arizona and ecological studies. All manuscripts are peer-reviewed by specialists. Acceptance for publication will be at the discretion of the editor. At least 30 printed copies of each issue are distributed to libraries in the United States, Europe, and Latin America. Anyone may download copies free of charge at <http://lifesciences.asu.edu/herbarium/canotia.html>.

Canotia is named for *Canotia holacantha* Torr. (Celastraceae), a spiny shrub or small tree nearly endemic to Arizona.

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CANOTIA HOLACANTHA ON ISLA TIBURÓN, GULF OF CALIFORNIA, MEXICO

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ABSTRACT

Canotia holacantha Torrey is reported from the Gulf of California, Mexico on Isla Tiburón. This population is isolated from its closest conspecifics in northern Sonora by 230 km and is best explained as a Pleistocene relict. Previous reports of this species on Tiburón and differences between other “crucifixion thorns” are explained.

INTRODUCTION

We report *Canotia holacantha* Torrey (crucifixion thorn, *corona de cristo*, *junco*; Celastraceae) from the heart of the Sonoran Desert on the high peaks of Isla Tiburón. Previously, Turner et al. in *Sonoran Desert Plants: An Ecological Atlas* (1995: 145) reported *Canotia* on Isla Tiburón based on collections of *Castela polyandra* Moran & Felger made by Richard Felger (9359, 10135, ARIZ). In recent conversations and data checking with Ray Turner it became clear that these collections were incorrectly ascribed to *Canotia holacantha* in the Atlas. It is with pleasure that we now report, with vouchers, the intriguing occurrence of *C. holacantha* on the island:

Mexico. Sonora, Isla Tiburón: exposed upper ridges of the Sierra Kunkaak, 825 m, to 1.3 m tall and wide, 28°57'49.08"N, 112°19'40.37"W, *B. Wilder* 07-549 with Brad Boyle, Richard Felger, and José Ramón Torres (ARIZ, SD, MEXU); east-facing slope just below high ridge, 800 m, ca. 1/2 m tall, population of ca. 10 individuals, 28°57'57.27"N, 112°19'47.75"W, *B. Wilder* 07-528 with Brad Boyle, Richard Felger, and José Ramón Torres (ARIZ, USON).

DISCUSSION

Two local subpopulations of *C. holacantha* were encountered at the highest elevations on the island, each with several shrubs, mostly ca. 1 m tall. These individuals are notably smaller than those that are encountered throughout the primary range of the species in central and northern Arizona, where it is often a thick-trunked "shrub or small tree 2–6 (occasionally 10) m tall" (Turner et al. 1995: 145). Browsing by the large population of bighorn sheep, introduced on the island in 1975, might be responsible for the relatively dwarfed stature of these plants, or it is very likely caused by the harsh conditions that the plants are subjected to in this locality with windswept rock ridges and minimal soil (Figs. 1, 2).

Canotia holacantha has a distribution that is transitional into higher, more northern vegetation types in and to the north of the Sonoran Desert. This discovery is the southernmost locality for the species, and extends its range 230 km to the southwest. The nearest populations are on the mainland in northern Sonora, where it is known from a few small populations, such as those in the foothills southeast of Magdalena de Kino, the nearby Sierra Babiso, and the Altar-Tubutama area (Turner et al. 1995, Felger et al. 2001). It has also recently been collected in the Sierra Madera near Imuris in northern Sonora (Fig. 3, *A.L. Reina-G.* 2005-654, ARIZ, USON).

The presence of *C. holacantha* on an island in the Gulf of California is best explained as a Pleistocene relict (Turner et al. 1995) that is indicative of a historic vegetation much different than the current suite of desert species found there. Reconstruction of Pleistocene vegetation through much of what is now the Sonoran Desert, by analysis of fossil packrat middens, confirms that in the late Wisconsin (the last glacial period prior to 11,000 yr B.P.) a relatively mesic woodland vegetation and flora was present in the low desert regions (Betancourt et al. 1990). Ice age dominants included *Pinus monophylla* Torrey & Frémont (singleleaf pinyon; Pinaceae), *Juniperus osteosperma* (Torrey) Little (Utah juniper; Cupressaceae), *Quercus turbinella* Greene (shrub live oak; Fagaceae), and *Yucca brevifolia* Engelm (Joshua tree; Agavaceae). The early Holocene from 11,000 to about 9,000 yr B.P. was a transitional period with some mesic species, including *Juniperus californica* Carrière (California juniper) and *Y. brevifolia* in the Tinajas Altas Mountains in southwestern Arizona. The only published packrat midden records from Sonora are 10,000 year Holocene sequences from the Hornaday Mountains in

the Gran Desierto in northwestern Sonora, and the Sierra Bacha on the coast of the Gulf of California (Van Devender 1990, Van Devender et al. 1994). Ice age climates with greater winter rainfall and cooler summers favored the expansion of northern and higher elevation species southward and into what are now desert lowlands. No paleovegetation analysis, however, has been conducted for any island in the Gulf of California, a prospect made even more intriguing via this discovery.

The flora of Isla Tiburón, especially the extensive and rugged Sierra Kunkaak (ca. 1,000 m elevation), has biogeographical connections to the entirety of the Sonoran Desert, including the central and southern Baja California peninsula and the northern and southern edges of the desert. Examples of disjunct Sierra Kunkaak populations are: species with nearest populations to the south in the more “tropical” parts of the Guaymas region (e.g., *Lantana velutina* M. Martens & Galeotti; Verbenaceae); species at a higher elevation than the desert in northeastern Sonora (e.g., *Fraxinus gooddingii* Little; Oleaceae); species primarily in Baja California Norte with populations on Tiburón and a few other Midriff islands, and extremely limited localities in Sonora (e.g., *Sideroxylon leucophyllum* S. Watson; Sapotaceae); species with wide distribution in Baja California Sur and isolated Sonoran populations (e.g., *Tetramerium fruticosum* Brandegee; Acanthaceae); and species in Baja California Sur in the Cape Region and Isla Cerralvo (e.g., *Diospyros intricata* (A. Gray) Standley; Ebenaceae). This biogeographically heterogeneous flora of a “sky island” within an island shows evidence of a high degree of connectivity at the center of the Sonoran Desert. The presence of the northerly-distributed *Canotia holacantha*, among the most recent of botanical discoveries on Tiburón (Wilder et al. 2007), adds a Pleistocene temporal dimension to these enigmatic “sky island” populations.

The only fossil record for *Canotia holacantha* is from an 11,100 yr B.P. midden from Picacho Peak, Pinal County, Arizona (Van Devender et al. 1991), reflecting a southeastward expansion of this species in the late Wisconsin woodlands. Subsequently a relict population of *Canotia holacantha* was discovered in the Waterman Mountains in Pima County about 50 km southeast of Picacho Peak (Van Devender 2002-1152, ARIZ).

The isolated populations near Tubutama and Magdalena de Kino, and the newly-discovered population in the Sierra de la Madera suggest that during the winter rainfall Pleistocene glacial periods, *Canotia holacantha* and other more cold-tolerant scrub, chaparral, and woodland species were present throughout the modern Arizona Upland subdivision of the Sonoran Desert. The record of *C. holacantha* on Isla Tiburón is a remarkable range extension from the north into a zone that, as has been reported, was more like Baja California during the Pleistocene (Van Devender et al. 1994). Modern desert communities were present for only about five percent of the 2.4 million years of the Pleistocene, while ice age woodlands in the desert lowlands persisted for about ninety percent of this period (Van Devender 2000). Considering this, isolated populations of *C. holacantha* and other ice age expanders are relicts of an era when woodlands were the predominant vegetation in Sonoran Desert area, and the Arizona Upland was greatly contracted.

Canotia holacantha is one of three unrelated “crucifixion thorn” shrubs on Isla Tiburón, each with a distinctive growth-form. *Canotia holacantha* occurs at

peak elevations and has terete stems, bisexual flowers, and persistent woody capsules, 1.5–2 cm long, with 5 carpels that split apically into awned valves. *Koeberlinia spinosa* Zuccarini and *Castela polyandra* occur only at lower elevations. *Koeberlinia* has slender, terete twigs, bisexual flowers, and non-persistent, rounded fruits 3–3.5 mm in diameter that dry capsule-like. It is common on the Agua Dulce Valley floor (southward from Tecomate) where it often becomes a small tree ca. 4 m tall (Felger & Moser 1985). It is an infrequent low shrub in the Valle de Aguila at the northeast part of the island and in Arroyo Sauzal at the south end of the island. *Castela polyandra* occurs on the eastern bajada of the island in a narrow band parallel to the shore, just inland from the *Frankenia* zone and extending into the lower mixed desertscrub vegetation (Felger & Lowe 1976). It is a low, spreading shrub, reaching up to ca. 1 m in height, that has laterally compressed stems, a sparse foliage of leaves, often 0.5–2.5 cm long, that quickly become deciduous, male and female flowers are on separate plants, and the fruits are 1–1.5 cm long, fleshy and not persistent (Moran & Felger 1968).

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LITERATURE CITED

- BETANCOURT, J.L., T.R. VAN DEVENDER and P.S. MARTIN. 1990. *Packrat Middens: The last 40,000 years of biotic change*. University of Arizona Press, Tucson.
- FELGER, R.S., M.B. JOHNSON and M.F. WILSON. 2001. *Trees of Sonora, Mexico*. Oxford University Press, New York.
- FELGER, R.S. and C.H. LOWE. 1976. *The Island and Coastal Vegetation and Flora of the Gulf of California, Mexico*. Natural History Museum of Los Angeles County, Contributions in Science No. 285.
- FELGER, R.S. and M.B. MOSER. 1985. *People of the Desert and Sea: Ethnobotany of the Seri Indians*. University of Arizona Press, Tucson (Reprinted 1991).

MORAN, R. and R.S. FELGER. 1968. *Castela polyandra*, a new species in a new section; union of *Holacantha* with *Castela* (Simaroubaceae). *Transactions of the San Diego Society of Natural History* 15(4): 31–40.

TURNER, R.M., J.E. BOWERS and T.L. BURGESS. 1995. *Sonoran Desert Plants: An Ecological Atlas*. University of Arizona Press, Tucson.

VAN DEVENDER, T.R. 1990. Late Quaternary vegetation and climate of the Sonoran Desert, United States and Mexico. Pp. 134–165. In: J.L. Betancourt, T.R. Van Devender and P.S. Martin (eds.). *Packrat Middens: The Last 40,000 Years of Biotic Change*. University of Arizona Press, Tucson.

VAN DEVENDER, T.R. 2000. The deep history of the Sonoran Desert. Pp. 61–69. In S.J. Phillips and P.W. Comus (eds.). *A Natural History of the Sonoran Desert*. Arizona-Sonora Desert Museum Press, Tucson and University of California Press, Berkeley.

VAN DEVENDER, T.R., T.L. BURGESS, J.C. PIPER and R.M. TURNER. 1994. Paleoclimatic implications of Holocene plant remains from the Sierra Bacha, Sonora, Mexico. *Quaternary Research* 4: 99–108.

VAN DEVENDER, T.R., J.I. MEAD and A.M. REA. 1991. Late Quaternary plants and vertebrates from Picacho Peak, Arizona, with emphasis on *Scaphiopus hammondi* (western spadefoot). *Southwestern Naturalist* 36: 302–314.

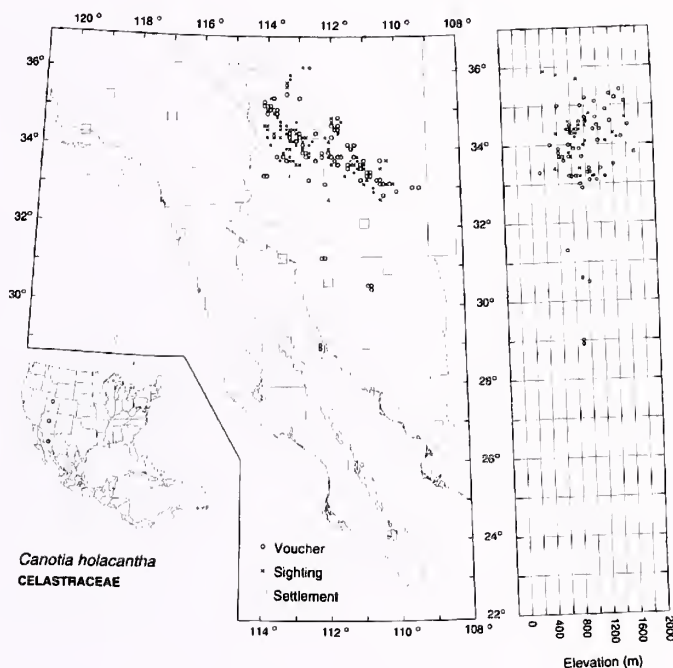
WILDER, B.T., R.S. FELGER, H. ROMERO-MORALES and A. QUIJADA-MASCAREÑAS. 2007. New plant discoveries for the Sonoran Islands, Gulf of California, Mexico. *Journal of the Botanical Research Institute of Texas* 1: 1203–1227.



***Canotia holocantha* on Isla Tiburón** Figure 1. *Canotia holocantha* on the exposed upper ridges of Isla Tiburón (image by Benjamin Wilder 26 October 2007).



***Canotia holocantha* on Isla Tiburón** Figure 2. This plant (Wilder 07-549) is 1.3 m tall and was the largest individual of *Canotia holocantha* seen on the island (image by Benjamin Wilder 26 October 2007).



***Canotia holocantha* on Isla Tiburón** Figure 3. Distribution of: *Canotia holocantha* (modified from Turner et al. 1995 and used with permission of Raymond M. Turner).

A PRELIMINARY CHECKLIST OF ARIZONA SLIME MOLDS

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and

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ABSTRACT

A checklist of 147 species of slime molds is presented for the state of Arizona. This total represents approximately one-tenth of all species known from the eukaryotic slime mold groups. This is remarkable in that a majority of the records here have been derived from studies focusing on arid-lands. The checklist was compiled primarily from records of Arizona slime molds in scientific publications and was supplemented with data from the U.S. National Fungus Collection, the Global Biodiversity of Eumycetozoa database, as well as personal herbaria. Fifteen species, *Arcyria veriscolor* W. Phillips, *Badhamia foliicola* Lister, *Echinostelium elachiston* Alexop., *Hemitrichia leiocarpa* (Cooke) Lister, *Licea variabilis* Schrad., *Lindbladia tubulina* Fr., *Perichaena microspora* Penz. & Lister, *Physarum bitectum* G. Lister, *Physarum confertum* T. Macbr., *Physarum crateriforme* Petch, *Physarum echinosporum* Lister, *Physarum flavicomum* Berk., *Physarum newtonii* T. Macbr., *Stemonitis nigrescens* Rex, and *Trichia alpina* (R.E. Fr.) Myel., are considered as new records for the state, although identifications of these species have not been verified by the authors. The data presented here contributes to our understanding of slime mold biodiversity and biogeography.

INTRODUCTION

The term 'slime mold' has been applied to several groups of organisms characterized by a life cycle that includes motile amoebae-like cells, that normally aggregate to form multinucleate or multicellular structures (assimilative and/or reproductive), and produce sessile or stalked sporulating structures. Although slime molds share this common generalized life cycle, they are not all closely related, and modern phylogenetically based classification schemes place them within five different subgroups of three major eukaryotic clades (see Baldauf 2003). An additional prokaryotic group, the myxobacteria (δ proteobacteria; not treated here), are also similar in that individual cells aggregate and eventually form spores; however, these organisms lack flagella and achieve motility by 'gliding' (Shimkets & Woese 1992, Dworkin & Kaiser 1993).

Historically it has been acknowledged that slime molds comprise distinct groups, and their polyphyletic nature has been speculated for over a century (de

Bary 1887). Alexopoulos et al. (1996) recognized five separate phyla: the *Labyrinthulomycota* (net slime molds), *Plasmodiophoromycota* (endoparasitic slime molds), *Dictyosteliomycota* (dictyostelid cellular slime molds), *Acrasiomycota* (acrasid cellular slime molds), and *Myxomycota* (true slime molds or myxomycetes). Although the nomenclature surrounding these organisms suggests relatedness to the *Eumycota* (true fungi), they are not contained in the opisthokonts clade (i.e., animals + fungi; Baldauf 2003); however, mycologists have traditionally been involved in their study (Ainsworth 1976). To distinguish the core monophyletic group of slime molds (myxomycetes, dictyostelids, and protostelids) as a distinct group, separate from the fungi, the terms mycetozoans or eumycetozoans has been informally used by some authors (e.g., Olive 1975, Spiegel et al. 1995).

Slime mold diversity is perhaps best reflected in the variety of forms that are exhibited by their fruiting structures. Though minute (many less than 2 mm tall), these forms can be quite beautiful (Fig. 1; and see the *Eumycetozoan Project*, <http://slimemold.uark.edu>), if one takes the time to examine them closely. The most recognizable slime molds are found within the *Myxomycota*, and this group contains the majority of described species (ca. 1000; Schnittler et al. 2006), their plasmodia (Fig. 1b, multinucleate assimilative phase) can be large and colorful, and their fruiting bodies, unlike those found in other groups (e.g., *Dictyosteliomycota*), are often visible to the unaided eye. Others are also familiar; for example, the ‘slug’ forming ‘social amoeba’ *Dictyostelium discoideum* is a well-known model organism used by researchers to study cell differentiation (Alexopoulos et al. 1996). In general, these organisms are phagotrophic microbial predators, the vegetative phase feeding on microscopic organisms such as bacteria, fungi, or protozoans. As with fungi, the substrata (e.g., bark, dung, decaying wood) on which slime molds are found may be of importance as these organisms can be associated with specific macro- or micro-habitats (e.g., ‘succulenticolous’ myxomycetes can be encountered in arid-lands on decaying succulents, Lado et al. 2002).

Slime molds have been recorded throughout the world and are well known from temperate forests, although they occur in a wide range of habitats – from tropical forests to alpine and arctic ecosystems (e.g., Martin & Alexopoulos 1969, Ing 1994, Alexopoulos et al. 1996, Stephenson & Laursen 1998, Schnittler & Stephenson 2000). Because these organisms require moisture for an extended period of time in order to complete their life cycles, their occurrence in deserts may seem remarkable; however, several studies have documented a notable diversity of slime molds from arid regions around the globe (e.g., Evenson 1961, Faurel et al. 1965, Ramon 1968, Blackwell & Gilbertson 1980a & 1984, Novozhilov & Golubeva 1986, Schnittler & Novozhilov 2000, Schnittler 2001, Lado et al. 2002, Novozhilov et al. 2003, Novozhilov et al. 2006). In these arid systems, slime molds are likely to be encountered on dead plant tissue of cacti and agaves, which can retain moisture long enough to support slime mold growth (Blackwell & Gilbertson 1980a, Ing 1994, Lado et al. 2002). The majority of Arizona slime mold records have originated within studies that focused on arid-lands in general and the Sonoran Desert in particular, and most of these studies have relied primarily on the use of ‘moist-chamber cultures’ to induce plasmodial and sporulating structures (see Gilbert & Martin 1933, Alexopoulos 1964).

The first accounts of Arizona slime molds come from Evenson (1961), who recorded 63 species that were "...observed in an area that is within a radius of 90 miles of Tucson...." Blackwell and Gilbertson (1980a) again focused on localities near Tucson and reported on 52 species. Within the twentieth century, other reports were sparse (e.g., Olive & Stoianovitch 1966, Cavender & Raper 1968, Ranzoni 1968, Raper & Alexopoulos 1973, Cooke 1985, M^cGuinness & Haskins 1985, Clark & Haskins 1998); however, records from central and northern Arizona were accumulated and species new to science were reported from the state (e.g., Keller & Brooks 1976a–b & 1977, Blackwell & Gilbertson 1980b, Whitney & Keller 1980, Whitney 1980, Cox 1981). The twenty-first century brought more records from the northern parts of the state. Brian (2000) reported on two species from the Grand Canyon (only one identified to species) and the study of Novozhilov et al. (2003) from the Colorado Plateau brought 48 additional records.

METHODS

The methods used in this paper follow, for the most part, those of Bates (2006). The literature search was aided considerably by the appearance on-line of early editions of journals, such as *Mycologia*, and technology allowing for journal content searches (e.g., JSTOR, <http://www.jstor.org>; Google Scholar, <http://scholar.google.com>). On-line searches for slime mold records in the *Planetary Biodiversity Inventories (PBI): Global Biodiversity of Eumycetozoans* database (<http://slimemold.uark.edu>) and for specimens in the U.S. National Fungus Collections (BPI; Farr et al. 2007) were also carried out. From this effort, 55 species records for Arizona were obtained. A number of species cited from the literature are also deposited as specimens in herbaria (e.g., Blackwell & Gilbertson 1980a). Data from the literature and herbarium databases were supplemented by records acquired from the author's personal herbarium (hb. Bates) and also that of Y.K. Novozhilov (hb. Novozhilov).

A database was compiled from all of the individual records located (303 in total). Each entry in the database cited the source of the record and the binomial as it originally appeared in publication or in a database record. Synonymy, currently accepted names, and the classification system used conform to Lado (2001), the 'On-Line Nomenclatural Information System of the Eumycetozoans' (<http://www.eumycetozoa.com>), and the CABI Index Fungorum (<http://www.indexfungorum.org>). Entries in the checklist published here are followed by annotations in brackets, which indicate the record source/s for each species included (see *Annotation Key* below). If no previous published report of the species' occurrence in Arizona existed, then the annotation 'NR' indicates a new record. The on-line Checklist of Arizona Macrofungi has been relocated to a new URL (<http://www.azfungi.org/checklist>) and has been restructured to include slime mold records published here in addition to more than one-thousand species of macrofungi documented previously from the state (see Bates 2006). The on-line checklist will continue to be updated as additional records become available.

RESULTS, DISCUSSION, AND CONCLUSIONS

Records of one hundred forty-seven Arizona slime molds from 14 families, 3 phyla (*Labyrinthulomycota*, *Dictyosteliomycota*, and *Myxomycota*), and 2 major eukaryotic groups (Chromista and Protozoa) are reported in this checklist. While the majority of these (~90%) have been previously reported from the literature, a total of fifteen species, *Arcyria veriscolor* W. Phillips, *Badhamia foliicola* Lister, *Echinostelium elachiston* Alexop., *Hemitrichia leiocarpa* (Cooke) Lister, *Licea variabilis* Schrad., *Lindbladia tubulina* Fr., *Perichaena microspora* Penz. & Lister, *Physarum bitectum* G. Lister, *Physarum confertum* T. Macbr., *Physarum crateriforme* Petch, *Physarum echinosporum* Lister, *Physarum flavicomum* Berk., *Physarum newtonii* T. Macbr., *Stemonitis nigrescens* Rex, and *Trichia alpina* (R.E. Fr.) Myel., are reported from the state for the first time. These new records are tentative, however, as the authors have not been able to verify the validity of these identifications, most of which originated from the BPI specimen database and *Global Biodiversity of Eumycetozoans* database. Furthermore, it was beyond the scope of this project and the expertise of the authors to confirm identifications for each record; therefore, the checklist should be considered preliminary and some inaccuracies may exist. Despite these faults, we feel that publishing a preliminary checklist such as this serves a purpose in that it provides a starting point from which future studies can precede – errors, once discovered, can then be corrected in the on-line checklist (<http://www.azfungi.org/checklist>). In the very least, this publication serves to catalog the slime mold literature for the state.

The extent of global slime mold diversity is still poorly known; however, it appears that their numbers are less than fungi, which estimates place at 700,000 to 1.5 million species world-wide, or more (Hawksworth 2001, Schmit & Mueller 2007). Considering that less than 1500 species of slime molds are described (Schnittler et al. 2006), it is remarkable that this checklist, based primarily on studies of arid-lands, contains approximately one-tenth of all known species. On going studies such as the *Tree Canopy Biodiversity in the Great Smoky Mountains National Park* (see Snell & Keller 2003, Keller et al. 2004) and the *PBI: Global Biodiversity of Eumycetozoans* project (see Schnittler et al. 2006) continue to make contributions to our understanding of slime molds and new species are being described; however, comprehensive knowledge of their diversity is still lacking. We hope this paper will encourage further study of these unique organisms within Arizona (or elsewhere) as it is likely that, with concentrated effort and exploration of additional habitats (e.g., mid- to high-elevation mesic forests of the state), new species will be discovered and additional records can be obtained.

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Slime molds Figure 1. Diversity in slime molds (forms visible to the unaided eye): (a) *Mucilago* sp., an example of the spore forming phase of the slime mold life cycle; (b) Slime mold plasmodium, an example of the assimilative phase of the slime mold life cycle; (c) *Physarum* sp. sporangia on wood; (d) *Lycogala epidendrum* sporangia on rotting wood.

PRELIMINARY CHECKLIST OF ARIZONA SLIME MOLDS

□ CHROMISTA

• LABYRINTHULOMYCOTA

LABYRINTHULOMYCETES

LABYRINTHULULALES

Labyrinthulaceae

Labyrinthula terrestris D.M. Bigelow, M.W. Olsen & Gilb. [1]

□ PROTOZOA

• DICTYOSTELIOMYCOTA

DICTYOSTELIOMYCETES

DICTYOSTELIALES

Dictyosteliaceae

Polysphondylium pallidum Olive [6]

• MYXOMYCOTA

MYXOMYCETES

ECHINOSTELIALES

Echinosteliaceae

Echinostelium apitectum K.D. Whitney [20,27]
Echinostelium arboreum H.W. Keller & T.E. Brooks [14]
Echinostelium coelocephalum T.E. Brooks & H.W. Keller [15,17,20,24,27]
Echinostelium colliculosum K.D. Whitney & H.W. Keller [2,20,24,25,27]
Echinostelium corynophorum K.D. Whitney [20,27]
Echinostelium elachiston Alexop. [NR,26]
Echinostelium fragile Nann.-Bremek. [17,24]
Echinostelium minutum de Bary [2,7,12,20,26,27,29]

LICEALES

Cribrariaceae

Cribraria cancellata (Batsch.) Nann.-Bremek. [12,29]
Cribraria violacea Rex [20,27]
Lindbladia tubulina Fr. [NR,29]

Liceaceae

Licea belmontiana Nann.-Bremek. [20,27]
Licea castanea G. Lister [20,27]
Licea denudescens H.W. Keller & T.E. Brooks [20,27]

Licea inconspicua T.E. Brooks & H.W. Keller [20,27]

Licea kleistobolus G.W. Martin [12,20,27]

Licea nannengae Pando & Lado [20,27]

Licea parasitica (Zukal) G.W. Martin [2,20,27]

Licea pedicellata (H.C. Gilbert) H.C. Gilbert [2]

Licea pseudoconica H.W. Keller & T.E. Brooks [2,18]

Licea tenera E. Jahn [20,27]

Licea testudinacea Nann.-Bremek. [20,27]

Licea variabilis Schrad. [NR,26]

Reticulariaceae

Lycogala epidendrum (J.C. Buxb. ex L.) Fr. [5,10,12,26,28,29]

Lycogala flavofuscum (Ehrenb.) Rostaf. [13]

Tubifera ferruginosa (Batsch) J.F. Gmel. [10]

PHYSARALES

Didymiaceae

Diderma effusum (Schwein.) Morgan [2]

Diderma radiatum (L.) Morgan [12,26]

Diderma simplex (Schroet.) G. Lister [2]

Diderma trevelyanii (Grev.) Fr. [12]

Didymium anellus Morgan [2,12,20,27]

Didymium difforme (Pers.) Gray [20,27]

Didymium dubium Rostaf. [2,12,20,27]

Didymium eremophilum M. Blackw. & Gilb. [2,3,4]

Didymium inconspicuum Nann.-Bremek. & D.W. Mitch. [20,27]

Didymium iridis Fr. [2,20,27]

Didymium karstensii Nann.-Brem. [2]

Didymium melanospermum (Pers.) T. Macbr. [12,29]

Didymium mexicanum G. Moreno, Lizarraga & Illana [20,27]

Didymium minus (Lister) Morgan [12]

Didymium nigripes (Link) Fr. [2,23]

Didymium quitense (Pat.) Torrend [20,27]

Didymium squamulosum (Alb. & Schwein.) Fr. [20,27]

Didymium vaccinum (Durieu & Mont.) Buchet [2,12]

Didymium verrucosporum A.L. Welden [20,27]

Lepidoderma carestianum (Rabenh.) Rostaf. [12]

Mucilago crustacea P. Micheli ex F.H. Wigg. [12,26,28]

Physaraceae

- Badhamia affinis* Rostaf. [2]
Badhamia apiculospora (Hark.) Eliasson & N. Lundq. [20,27]
Badhamia foliicola Lister [NR,26]
Badhamia gracilis (Macbr.) Macbr. [2,4,9,26]
Badhamia macrocarpa (Ces.) Rostaf. [2,12,26]
Badhamia melanospora Speg. [20,27]
Badhamia panicea (Fr.) Rostaf. [2,12]
Badhamiopsis ainoae (Yamash.) T.E. Brooks & H.W. Keller [17]
Craterium leucocephalum (Pers.) Ditmar [2]
Craterium minutum (Leers) Fr. [12]
Fuligo cinerea (Schw.) Morgan [2,20,27,29]
Fuligo intermedia T. Macbr. [10,26]
Fuligo megaspora Sturgis [2]
Fuligo septica var. *septica* (L.) F.H. Wigg. [2,12,29]
Leocarpus fragilis (Dicks.) Rostaf. [12,29]
Physarum auriscalpium Cooke [2,29]
Physarum bitectum G. Lister [NR,29]
Physarum bivalve Pers. [20,27]
Physarum cinereum (Batsch) Pers. [12,20,27,29]
Physarum compressum Alb. & Schwein. [2,12]
Physarum confertum T. Macbr. [NR,29]
Physarum crateriforme Petch [NR,29]
Physarum decipiens M.A. Curtis [20,27]
Physarum didermoides (Ach. ex Pers.) Rostaf. [2]
Physarum echinosporum Lister [NR,29]
Physarum flavicomum Berk. [NR,29]
Physarum galbeum Wingate [12]
Physarum lateritium (Berk. & Ravenel) Morgan [2]
Physarum leucophaeum Fr. [2,20,27,29]
Physarum leucopus Link [2]
Physarum luteolum Peck [2]
Physarum mutabile (Rostaf.) G. Lister [2,12]
Physarum newtonii T. Macbr. [NR,26]
Physarum notabile T. Macbr. [2,12,20,27,29]
Physarum nucleatum Rex [2]
Physarum nudum T. Macbr. [20,27]
Physarum nutans Pers. [12,29]
Physarum ovisporum G. Lister [11]
Physarum pusillum (Berk. & M.A. Curtis) G. Lister [2,12,29]
Physarum straminipes Lister [2,4]
Physarum tenerum Rex [12]
Physarum vernum Sommerf. [2]
Protophysarum phloiogenum M. Blackwell & Alexop. [4,20,27,29]
Willkommilangea reticulata (Alb. & Schwein.) Kuntze [20,27]

Stemonitidaceae

- Clastoderma debaryanum* A. Blytt. [12,29]
Collaria arcyryonema Rostaf. [12]
Collaria lurida (Lister) Nann.-Bremek. [2,12,19,29]
Colloderma oculatum (Lippert) G. Lister [2]
Comatricha irregularis Rex [12]
Comatricha laxa Rostaf. [2,8,12,20,27,29]
Comatricha nigra (Pers.) J. Schröt. [2,12,29]
Comatricha pulchella (C. Bab.) Rostaf. [2,12,20,27,29]
Comatricha tenerima (M.A. Curtis) G. Lister [12]
Enerthenema papillatum (Pers.) Rostaf. [20,27]
Lamproderma sauteri Rostaf. [12]
Macbrideola decapillata H.C. Gilbert [20,27]
Macbrideola declinata T.E. Brooks & H.W. Keller [20,27]
Macbrideola scintillans H.C. Gilbert [20,27]
Paradiacheopsis cribrata Nann.-Bremek. [20,27]
Paradiacheopsis fimbriata (G. Lister & Cran) Hertel ex Nann.-Bremek. [20,27,29]
Stemonitis axifera (Bull.) T. Macbr. [10,12]
Stemonitis flavogenita E. Jahn [2,12]
Stemonitis fusca Roth [12,29]
Stemonitis nigrescens Rex [NR,26]
Stemonitis pallida Wingate [12]
Stemonitis smithii T. Macbr. [10]
Stemonitis virginensis Rex [12]
Stemonitopsis aequalis (Peck) Y. Yamam. [12]
Stemonitopsis typhina (F.H. Wigg.) Nann.-Bremek. [12,29]

Incertae sedis

- Kelleromyxa fimicola* (Dearn. & Bisby) Eliasson [2,12]

TRICHIALES**Arcyriaceae**

- Arcyria cinerea* (Bull.) Pers. [2,10,12,26]
Arcyria denudata (L.) Wettst. [10]
Arcyria incarnata (Pers.) Pers. [12]
Arcyria insignis Kalchbr. & Cooke [2,12]
Arcyria nutans (Bull.) Grev. [12,26,29]
Arcyria veriscolor W. Phillips [NR,26]

Dianemataceae

- Calomyxa metallica* (Berk.) Nieuwl. [12]

Trichiaceae

- Hemitrichia calyculata* (Speg.) M.L. Farr [12]
Hemitrichia clavata (Pers.) Rostaf. [12]

Hemitrichia leiocarpa (Cooke) Lister [NR,26]
Hemitrichia serpula (Scop.) Rostaf. [12,26]
Metatrichia vesparium (Batsch.) Nann.-
 Bremek. ex G.W. Martin & Alexop.
 [10,12,26,29]
Perichaena chrysosperma (Curr.) Lister
 [2,12,29]
Perichaena corticalis (Batsch) Rost.
 [2,4,12,20,27]
Perichaena depressa Lib. [2,12,20,27]
Perichaena microspora Penz. & Lister [NR,26]
Perichaena quadrata T. Macbr. [20,27]
Perichaena vermicularis (Schwein.) Rostaf.
 [2,12,20,26,27]
Trichia affinis de Bary [12]
Trichia alpina (R.E. Fr.) Myel. [NR,26]
Trichia botrytis (J.F. Gmel.) Pers. [12]

Trichia favoginea (Batsch) Pers. [10]
Trichia persimilis P. Karst. [12,26,29]
Trichia pusilla (Hedw.) G.W. Martin [12]
Trichia subfusca Rex [20,27]
Trichia varia (Pers.) Pers. [12,26]

PROTOSTELIOMYCETES

PROTOSTELIALES

Ceratiomyxaceae

Ceratiomyxa fruticulosa var. *fruticulosa* (O.F.
 Mull.) T. Macbr. [12]

Protosteliaceae

Protosteliopsis fimicola (L.S. Olive) L.S. Olive
 & Stoian. [21,22]

Annotation Key. Annotations [in brackets] follow each taxon. These indicate records that are new for Arizona (e.g., have not previously been published in the literature) and cite the source of each record with a number (see *Literature Cited*):

NR - New Record for Arizona; **1** - Bigelow et al. 2005; **2** - Blackwell & Gilbertson 1980a; **3** - Blackwell & Gilbertson 1980b; **4** - Blackwell & Gilbertson 1984; **5** - Brian 2000; **6** - Cavender & Raper 1968; **7** - Clark & Haskins 1998; **8** - Clark & Haskins 2002; **9** - Clark et al. 2003; **10** - Cooke 1985; **11** - Cox 1981; **12** - Evenson 1961; **13** - Gilbertson et al. 1972; **14** - Haskins & McGuinness 1989; **15** - Haskins et al. 2000; **16** - Keller & Brooks 1976a; **17** - Keller & Brooks 1976b; **18** - Keller & Brooks 1977; **19** - McGuinness & Haskins 1985; **20** - Novozhilov et al. 2003; **21** - Olive 1967; **22** - Olive & Stoianovitch 1966; **23** - Raper & Alexopoulos 1973; **24** - Whitney 1980; **25** - Whitney & Keller 1980; **26** - BPI; **27** - hb. Novozhilov; **28** - hb. Bates; **29** - The *PBI: Global Biodiversity of Eumycetozoans* database, <http://slimemold.uark.edu/>

LITERATURE CITED

- AINSWORTH, G.C. 1976. *Introduction to the History of Mycology*. Cambridge University Press, Cambridge.
- ALEXOPOULOS, C.J. 1964. The rapid sporulation of some Myxomycetes in moist chamber culture. *Southwestern Naturalist* 9: 155–159.
- ALEXOPOULOS, C.J., C.W. MIMS and M. BLACKWELL. 1996. *Introductory Mycology*. 4th edn. John Wiley & Sons, New York.
- BALDAUF, S.L. 2003. The deep roots of Eukaryotes. *Science* 300: 1703–1706.
- BATES, S.T. 2006. A preliminary checklist of Arizona macrofungi. *Canotia* 2: 47–78.
- BIGELOW, D.M., M.W. OLSEN and R.L. GILBERTSON. 2005. *Labyrinthula terrestris* sp. nov., a new pathogen of turf grass. *Mycologia* 97: 185–190.
- BLACKWELL, M. and R.L. GILBERTSON. 1980a. Sonoran Desert Myxomycetes. *Mycotaxon* 11: 139–149.
- BLACKWELL, M. and R.L. GILBERTSON. 1980b. *Didymium eremophilum*: A new Myxomycete from the Sonoran Desert. *Mycologia* 72: 791–797.
- BLACKWELL, M. and R.L. GILBERTSON. 1984. Distribution and sporulation phenology of Myxomycetes in the Sonoran Desert of Arizona. *Microbial Ecology* 10: 369–377.
- BRIAN, N. 2000. Checklist of non-vascular plants of Grand Canyon National Park, Arizona: Kingdoms Monera, Protista, Fungi, and Plantae (Phylum Bryophyta). *Notulae Naturae* 474: 1–20.
- CAVENDER, J.C. and K.B. RAPER. 1968. The occurrence and distribution of Acrasieae in forest of subtropical and tropical America. *American Journal of Botany* 55: 504–513.
- CLARK, J. and E.F. HASKINS. 1998. Heterothallic mating systems in the *Echinostelium minutum* complex. *Mycologia* 90: 382–388.
- CLARK, J. and E.F. HASKINS. 2002. Reproductive systems of the myxomycetes *Comatricha laxa* and *Lamproderma arcyrionema*. *Nova Hedwigia* 75: 237–240.
- CLARK, J., E.F. HASKINS and S.L. STEPHENSON. 2003. Biosystematics of the Myxomycete *Badhamia gracilis*. *Mycologia* 95: 104–108.
- COOKE, W.D. 1985. The 1980 Arizona Foray. *Mycologia* 77: 168–171.
- COX, J.J. 1981. Notes on coprophilous Myxomycetes from the western United States. *Mycologia* 73: 741–747.
- DE BARY, A. 1887. *Comparative Morphology and Biology of the Fungi, Mycetozoa and Bacteria*. Clarendon Press, London.

DWORKIN, M. and D. KAISER (eds). 1993. *Myxobacteria II*. American Society for Microbiology Press, Washington, DC.

EVENSON, A. 1961. A preliminary report of the Myxomycetes of Southern Arizona. *Mycologia* 53: 137–144.

FARR, D.F., A.Y. ROSSMAN, M.E. PALM and E.B. M^cCRAY. 2007. *Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA*. <http://nt.ars-grin.gov/fungaldatabases/> (Accessed 2007 July 24).

FAUREL, L.G., J. FELDMANN and G. SCHOTTERS. 1965. Catalogue des Myxomycetes de l' Afrique du Nord. *Bulletin de la Société d'Histoire Naturelle de l' Afrique du Nord* 55: 9–35.

GILBERT, H.C. and G.W. MARTIN. 1933. Myxomycetes found on the bark of living trees. *University of Iowa Studies in Natural History* 15: 3–8.

GILBERTSON, R.L., E.R. CANFIELD and G.B. CUMMINS. 1972. Notes on fungi from the L.N. Goodding Research Area. *Journal of the Arizona-Nevada Academy of Science* 7: 129–138.

HASKINS, E.F. and M.D. M^cGUINNESS. 1989. Sporophore ultrastructure of *Echinostelium arboreum*. *Mycologia* 81: 303–307.

HASKINS, E.F., M.D. M^cGUINNESS and J. CLARK. 2000. Heterothallic mating systems in the Echinosteliales II. *Echinostelium coelocephalum*. *Mycologia* 92: 1080–1084.

HAWKSWORTH, D.L. 2001. The magnitude of fungal diversity: The 1.5 million species estimate revisited. *Mycological Research* 105: 1422–1432.

ING, B. 1994. The phytosociology of myxomycetes. *New Phytologist* 126: 175–201.

KELLER, H.W. and T.E. BROOKS. 1976a. Corticolous Myxomycetes IV: *Badhamiopsis*, a new genus for *Badhamia ainoae*. *Mycologia* 68: 834–841.

KELLER, H.W. and T.E. BROOKS. 1976b. Corticolous Myxomycetes V: Observations on the genus *Echinostelium*. *Mycologia* 68: 1204–1220.

KELLER, H.W. and T.E. BROOKS. 1977. Corticolous Myxomycetes VII: Contribution toward a monograph of *Licea*, five new species. *Mycologia* 69: 667–684.

KELLER, H.W., M. SKRABAL, U.H. ELIASSON and T.W. GAITHER. 2004. Tree canopy biodiversity in the Great Smoky Mountains National Park: ecological and developmental observations of a new myxomycete species of *Diachea*. *Mycologia* 96: 537–47.

LADO, C. 2001. Nomenmyx. A nomenclatural taxabase of Myxomycetes. *Cuadernos de Trabajo Flora Micológica Ibérica* 16: 1–221.

LADO, C., A. ESTRADA-TORRES, M. RAMIREZ and E. CONDE. 2002. A study of the succulenticolous Myxomycetes from arid zones of Mexico. *Scripta Botanica Belgica* 22: 58.

MARTIN, G.W. and C.J. ALEXOPOULOS. 1969. *The Myxomycetes*. University of Iowa Press, Iowa City.

M^cGUINNESS, M.D. and E.F. HASKINS. 1985. Genetic analysis of the reproductive system of the True Slime Mold *Comatricha lurida*. *Mycologia* 77: 646–653.

NOVOZHILOV, Y.K. and O.G. GOLUBEVA. 1986. Epiphytic myxomycetes from the Mongolian Altai and the Gobi desert. *Micologia i fitopatologia* 20: 368–374 [in Russian].

NOVOZHILOV, Y.K., D.W. MITCHELL and M. SCHNITTTLER. 2003. Myxomycete biodiversity of the Colorado Plateau. *Mycologica Progress* 2: 243–258.

NOVOZHILOV, Y.K., I.V. ZEMLIANSKAIA, M. SCHNITTTLER and S.L. STEPHENSON. 2006. Myxomycete diversity and ecology in the arid regions of the Lower Volga River Basin (Russia). *Fungal Diversity* 23: 193–241.

OLIVE, L.S. 1967. The Protostelida: A new order of the Mycetozoa. *Mycologia* 59: 1–29.

OLIVE, L.S. 1975. *The Mycetozoans*. Academic Press, New York.

OLIVE, L.S. and STOIANOVITCH. 1966. *Protosteliopsis*, a new genus of the Protostelida. *Mycologia* 58: 452–455.

RAMON, E. 1968. Myxomycetes of Israel. *Israel Journal of Botany* 17: 207–211.

RANZONI, F.V. 1968. Fungi isolated in culture from soils of the Sonoran Desert. *Mycologia* 60: 356–371.

RAPER, K.B. and C.J. ALEXOPOULOS. 1973. A Myxomycete with a singular myxamoebal encystment stage. *Mycologia* 65: 1284–1295.

SCHMIT, J.P. and G.M. MUELLER. 2007. An estimate of the lower limit of global fungal diversity. *Biodiversity and Conservation* 16: 99–111.

SCHNITTTLER, M. 2001. Ecology of Myxomycetes of a winter-cold desert in western Kazakhstan. *Mycologia* 93: 653–669.

SCHNITTTLER, M. and Y.K. NOVOZHILOV. 2000. Myxomycetes of the winter-cold desert in western Kazakhstan. *Mycotaxon* 74: 267–286.

SCHNITTTLER, M. and S.L. STEPHENSON. 2000. Myxomycete biodiversity in four different forest types in Costa Rica. *Mycologia* 92: 626–637.

SCHNITTTLER, M., M. UNTERSEHER and J. TESMER. 2006. Species richness and ecological characterization of myxomycetes and myxomycete-like organisms in the canopy of a temperate deciduous forest. *Mycologia* 98: 223–232.

SHIMKETS, L. and C.R. WOESE. 1992. A phylogenetic analysis of the myxobacteria: basis for their classification. *Proceedings of the National Academy of Sciences* 89: 9459–9463.

SNELL, K.L. and H.W. KELLER. 2003. Vertical distribution and assemblages of corticolous myxomycetes on five tree species in the Great Smoky Mountains National Park. *Mycologia* 95: 565–576.

SPIEGEL, F.W., S.B. LEE and S.A. RUSK. 1995. Eumycetozoans and molecular systematics. *Canadian Journal of Botany* 73: s738–s746.

STEPHENSON, S.L. and G.A. LAURSEN. 1998. Myxomycetes from Alaska. *Nova Hedwigia* 66: 425–434.

WHITNEY, K.D. 1980. The Myxomycete genus *Echinostelium*. *Mycologia* 72: 950–987.

WHITNEY, K.D. and K.W. KELLER. 1980. A new species of *Echinostelium*. *Mycologia* 72: 640–643.

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